

CANYONLANDS NATIONAL PARK RESEARCH SUMMARY 2011

1) Study Title: Riparian Ecological Site Study of Canyonlands National Park

Permit No.: CANY-2011-SCI-0001

Principal Investigator: Victor Parslow

Purpose of Scientific Study: The project is a study of the stream channel type and existing vegetation of the riparian areas in Canyonlands National Park. This data is necessary to complete the riparian Ecological Site Descriptions for the Park.

Findings/Accomplishments for 2011: Riparian vegetative data was collected in riparian areas of the park in order to develop Ecological Site Descriptions.

2) Study Title: Abundance Estimates for Colorado pikeminnow in the Green River Basin, Utah and Colorado.

Permit No.: CANY-2011-SCI-0002

Principal Investigator: Paul Badame

Purpose of Scientific Study: Obtain an accurate (unbiased) and reliable (precise) estimate of the adult population abundance and survival of Colorado pikeminnow that occupy the Green River study area.

Objectives:

1. Complete a minimum of three sampling passes through the five Green River Basin reaches listed to capture sub-adult and adult Colorado pikeminnow:

a) Green River between the confluence of the White River upstream to the lower end of Whirlpool Canyon (i.e., upper Rainbow Park).

b) White River between the confluence of the Green River upstream to Taylor Draw Dam,

c) Yampa River between Deerlodge Park and Craig, excluding Cross Mountain Canyon,

d) Green River from the White River confluence downstream to near Green River, Utah, and,

e) Green River from downstream of Green River, Utah, to the confluence with the Colorado River.

The LFL and CDOW will attempt up to six sampling passes in the Yampa River, in part associated with bass and northern pike removal projects, in order to obtain a more precise and accurate Colorado pikeminnow abundance estimate.

2. Obtain highest possible rates of capture of Colorado pikeminnow within concentration habitats and maximize number of individuals marked and captured on each sampling occasion.

3. Obtain estimates of probability of capture and abundance for Colorado pikeminnow in each of the five reach and for the entire study area. Razorback sucker data gathered concurrently will also be analyzed, mostly related to survival rate estimation.

Findings/Accomplishments for 2011: All expected sampling for this section was completed and the data was forwarded to CSU Boulder for compilation and analysis. Population estimates will be derived and reported in December of 2014 at the end of the 3-year sampling period.

3) Study Title: Population monitoring of humpback and bonytail chub in Cataract Canyon

Permit No.: CANY-2011-SCI-0003

Principal Investigator: Paul Badame

Purpose of Scientific Study: Goals: Maintenance of long term catch rate trend data, longitudinal distributions, and population size structures for humpback and bonytail within Cataract Canyon.

Objectives:

1. Complete one ten day pass each year sampling five sites within Cataract Canyon.

2. Obtain highest possible rates of capture of humpback and bonytail within concentration habitats and maximize number of individuals marked and captured at each sampling site.
3. Determine annual catch rate trend for chubs, examine population size structure, and compare longitudinal distribution to past years.

Findings/Accomplishments for 2011: Annual sampling was conducted October 4- 12, 2011 at two long-term trend monitoring sites and at rapid 12 (Figure 1). Daily mean flows ranged from 8,730 - 10,950 ft³/sec (Figure 2) and water temperatures ranged from 17.5 - 13°C. No sites were sampled below the "Big Drop" rapids. The higher than average fall flows precluded sampling at the long-term sampling site located between rapids 2 and 3, as all camp sites were submerged. Trammel nets were the only gear deployed during the 2011 sampling period, equipment malfunctions precluded electrofishing. During 2011 we had irreparable failure of four Smith-Root 5.0 generators. A total of 9 humpback chub were captured in 2011 via trammel nets during 366.8 hours of effort. The resulting catch rate for humpback chub was 0.024 humpback chub/net hr. humpback chub trammel net catch rates within cataract canyon remain stable and have shown no significant trend over the last 20 years; fluctuating between 0.010 and 0.035 fish per hour (Figure 3). Two humpback chubs were recaptured from 2005 sampling and both were found within the original ½ mile sampling site below rapid 5. The two chubs had grown 13 mm and 18 mm over the six year period. All humpback chub caught by trammel nets were adults (>150 mm) with a mean total length of 237.2 mm. The lack of juveniles was expected, as 1½ trammel nets are highly ineffective for capturing Gila smaller than 200 mm and electrofishing was not possible. The size structure of adult humpback chubs within Cataract Canyon remains narrowly distributed (Figure 4). No sites have been sampled below the big drop rapids since 2008 and it is unknown if chubs have expanded their range into this section of river. Due to the high site fidelity often observed in humpback chubs it is likely that re-colonization of this recently created habitat would be slow.

A total of 116 fish consisting of 12 species were captured by trammel nets in Cataract Canyon in 2010. Humpback chub, Razorback sucker, and Colorado pikeminnow made up 23.2% of the total sample and all native species combined were 31.9% of the total catch. Razorback sucker and channel catfish was the most common native and nonnative species present.

4) Study Title: Southern Utah Visitor Profile Study 2010

Permit No.: CANY-2011-SCI-0004

Principal Investigator: Emmett Steed

Purpose of Scientific Study: The purpose of this study is to understand Southern Utah's tourists, who stay overnight and travel more than 50 miles from their homes. The research seeks to answer the following questions:

1. What are the demographic characteristics of Southern Utah visitors?
2. What relationships exist among Southern Utah visitors in regard to place of origin, Southern Utah destinations visited, transportation utilized, activities selected while in Southern Utah, and trip expenditures?
3. Are there seasonal differences in origin, destinations, activities, and expenditures?
4. What are the information sources utilized by Southern Utah visitors?

Findings/Accomplishments for 2011: The Utah Office of Tourism partnered with the Southern Utah University Hospitality Research Center to conduct a Central/Southern Utah Visitor Profile study. Visitors to four Central Utah Counties and eight Southern Utah Counties were asked to complete surveys that were designed by three Southern Utah University professors. Visitors were asked to complete the surveys in four different seasons. The surveys were completed by hand, by returning an e-mail attachment, or by going to a website. There were 1,113 useable surveys completed. Four research questions guided the survey and analysis. Each question is stated below with a summary of its key findings.

I) What are the demographic characteristics of Southern Utah visitors?

The majority of visitors to the Central/Southern Utah area were: 1) over 45 years old; 2) have a household income greater than \$80,000; 3) spend \$100 per day in lodging and \$50 per day in food and beverage; 4) are married with no children under 17 years old in their household; 5) have at least a college education; and 6) visit National Parks frequently.

II) What relationships exist among Southern Utah visitors in regard to place of origin, Southern Utah destinations visited, transportation utilized, activities selected while in Southern Utah, and trip expenditures?

One of the most important findings was that geographic origin was not a valid predictor for places visited, activities selected, or expenditures made. In other words, no matter where people come from, once in Central/Southern Utah, they visit similar places, select similar activities, and spend similar amounts of money. The further away a visitor lived from Southern Utah, the more likely she was to travel by airplane.

III) Are there seasonal differences in origin, destinations, activities, and expenditures?

There were distinct patterns in visitors' origins, destinations, activities and expenditures by season. For example, domestic visitors from Pacific states were more likely to visit in the spring and summer while mountain state visitors were more likely to visit in the fall and winter ($X^2=.000$). International visitors vary by season as well. For example, English speaking tourists from Great Britain, Canada, Australia and New Zealand were more predominant in the spring; Winter received the most returning visitors 74% ($X^2=.045$). Destinations and activities varied by season as well. The destination seasonal patterns followed the activity patterns with national parks receiving the most visits in the summer and spring. The most popular activities included visiting national/state parks (79.5%), touring/sightseeing (70.4%), and hiking (65.2%). Visiting state/national parks increase in the spring and summer ($X^2=.020$). Touring and sightseeing follows this same pattern ($X^2=.003$), while hiking, as can be expected, decreases in the winter ($X^2=.027$). Visitors spent more money in the summer, spending more on lodging ($X^2=.002$), food ($X^2=.008$), rental cars ($X^2=.025$), recreation fees ($X^2=.004$), and park fees ($X^2=.009$) than in other seasons.

IV) What are the information sources utilized by Southern Utah visitors?

Southern Utah visitors stated the internet (82.6%), past experience (79%), and friends and relatives (63.5%) were either very influential or somewhat influential information sources.

5) Study Title: Collaborative Research: Fluid Flow and Growth of Active Salt Structures at Decadal Timescales, Paradox Basin - Utah

Permit No.: CANY-2011-SCI-0005

Principal Investigator: Karl Mueller

Purpose of Scientific Study: A broad, interdisciplinary analysis of faults, sinkholes, stream channels and topography of the Needles District in Canyonlands National Park. We seek to define how the landscape shifts in response to movement of rocks towards and into the Colorado River Canyon, how surface and ground water might drive or inhibit the movement, and whether deformation occurs by movement on actively expanding faults and sinkholes, or by gentle warping that is not visible to the naked eye. A much more detailed discussion of the scientific motivation for the study is presented in the attached research proposal.

Findings/Accomplishments for 2011: No activity was conducted this report year.

6) Study Title: NCPN Integrated Upland Monitoring in Canyonlands National Park

Permit No.: CANY-2011-SCI-0006

Principal Investigator: Jason Neff

Purpose of Scientific Study: The Northern Colorado Plateau Inventory and Monitoring Network (NCPN) of the National Park Service has identified upland ecosystem characteristics, processes, vegetation, and other biota as vital signs to be monitored.

Upland monitoring is intended to strike a balance between increasing fundamental understanding of dryland systems and providing managers early warning of undesirable change. It will document the variability in these systems while providing information needed for resource management decisions. Addressing these two goals will be accomplished partly through sampling design and data analysis. Some sites may be selected as representative of large portions of the landscape, others because of their management history. Evaluation of upland monitoring data in relation to other vital signs will facilitate identification of drivers and distinguishing "natural" from anthropogenic change. Additionally, plot data from this effort will be used in the classification and interpretation of remotely sensed data.

NCPN upland monitoring objectives for selected ecological sites:

1. Determine annual status and trends in ground cover (live and standing dead vegetation, litter, rock, biological soil crust, and bare ground); spatial pattern of vegetation by life form; soil aggregate stability and compaction as indicators of soil/site stability; hydrologic function, and nutrient cycling.
2. Determine annual status and trends in cover of biological soil crusts by species or morphological group.
3. Determine annual status and trends in cover of exotic plants in upland areas.

Findings/Accomplishments for 2011: 48 plots were sampled in grassland, shallow blackbrush and blackbrush/PJ ecosites in the Island in the Sky and Needles districts. All plots were checked for cultural resources during reconnaissance and again during establishment or revisit. All remaining reconnaissance was completed. An annual report of 2010 data was completed and sent to resource management staff.

7) Study Title: US Historical Climatology Network Modernization (USHCN-M) Canyonlands NP

Permit No.: CANY-2011-SCI-0007

Principal Investigator: Dennis Atkinson

Purpose of Scientific Study: Support for the Department of Commerce (DOC), National Oceanic and Atmospheric Administration's (NOAA) U.S. Regional Climate Reference Network (USRCRN) program (formerly, Historical Climatology Network Modernization, USHCN-M). The purpose of the USRCRN program is to provide a surface meteorological monitoring network that will allow scientists and the research community to have high quality data for use in climate evaluations and studies. These studies will allow determinations to be made with respect to regional climate signals, as they relate to different climate regimes. These climate studies will help predict and inform changes that affect humans, fauna, and flora, in addition to impacts on national, economic, and social infrastructures. This meteorological data will provide valuable on-site data for the National Park Service to monitor climate affects on sensitive elements throughout the parks and climate changes that affect the viability and use of the parks.

Findings/Accomplishments for 2011: This site is currently transmitting temperature and precipitation measurements. The latest data is available from the following URL:
<http://www.ncdc.noaa.gov/crn/usrcrn/>

8) Study Title: U.S. Geological Survey Research in Canyonlands NP (NOTE: This is a continuation of previous studies CANY-00013, CANY-00047, and CANY-00048)

Permit No.: CANY-2011-SCI-0008

Principal Investigator: Jayne Belnap

Purpose of Scientific Study: Maintaining native plant communities, biocrusts (composed of cyanobacteria, lichens, and mosses), soil stability and normal water and nutrient cycles in desert systems is critical to healthy ecosystem functioning. These particular ecosystem

processes are threatened by climate change (both altered temperature and precipitation), the compressional forces generated by the trampling of people and offroad driving, and invasive plants (especially annual weeds).

Climate change:

Temperatures are expected to rise by up to 6 oC by the year 2100 in this region. Models predict precipitation to show up to a 20% decline. Even with no change in precipitation, higher temperatures will decrease soil moisture by around 30%, stressing plants, biocrusts and altering nutrient cycles.

Compressional forces:

Soil compaction and disruption of biocrusts via trampling can result in decreased water availability to vascular plants through decreased water infiltration and increased albedo with possible decreased precipitation. Surface disturbance also generally causes accelerated soil loss through wind and water erosion, with a concomitant decline in soil fertility, and decreased diversity and abundance of soil biota. In addition, loss of biocrusts will lower nitrogen and carbon inputs and slow the decomposition of soil organic matter, resulting in lower nutrient levels in associated vascular plants. Cold desert systems are likely to be especially susceptible to these disruptions, due to the paucity of surface-rooting vascular plants for soil stabilization, fewer nitrogen-fixing higher plants, and lower soil temperatures, which slow nutrient cycles.

Invasive annual plants:

Many sites on the Colorado Plateau have been, or are being, invaded by annual weeds. Most of these sites have deep soils and were dominated by perennial grasslands before this invasion. Understanding what factors facilitate invasion; the impact of these invasions on native plants, biocrusts and soil nutrient cycles; and whether sites can recover naturally or need intervention is important in management of these sites. Desert soils may recover slowly from surface disturbances, especially given the expected reduction in soil moisture which is needed for recovery of soils, plants and biocrusts. Recovery from compaction and decreased soil stability is likely to be very slow. Reestablishment rates for soil bacterial and fungal populations are not known. The nitrogen fixation capability of soil requires at least 50 years for recovery. Recovery of crusts can be hampered by large amounts of moving sediment, and re-establishment can be extremely difficult in some areas. Areas invaded by annual weeds may never recover without restoration efforts.

This project addresses how climate change, land use, invasive of annual grasses and the interaction among these components will affect native plants, biocrusts, and soil nutrient cycling. There are four subsets of studies going on within the park to answer how soils, biocrusts, and plants will respond to 1) climate change/annual grass invasion in grasslands along a land use gradient (Virginia Park-Chesler Park-Squaw Flat), 2) climate change on various dominant shrub and grasses (rainout shelters), 3) climate change on dust production (BSNE network) and 4) land use and climate change (trample plots).

Note: This is a continuation of permit #s: CANY-00013 (CANY-2010-SCI-0005), CANY-00047 (CANY-2010-SCI-0017), CANY-00048, (CANY-2010-SCI-0004)

Findings/Accomplishments for 2011: Dust network (BSNE): We collected dust from BSNEs (dust collectors) at four sites on 3/9 and 3/15/11, 6/21 and 7/6/11, 10/21 and 11/1/11. Dust amounts ranged from 1.1 to 6.6 grams over the year with amounts steadily increasing from Spring through Fall. Dust levels were 4 times greater at 15 cm than at heights of 50 and 100 cm above the soil surface.

Trample: Trample plots were resampled in July 2011 for vegetation cover, cryptobiotic crust cover and soil stability. Plant and soil samples are being analyzed for nutrient content. All data will be summarized and analyzed once results are returned from the soil lab.

Rainout: We visited 3 grassland sites in the Needles district of Canyonlands to continue long-term data collection of sites. Repeat photos for biomass estimates as well as cryptobiotic crust and vegetation cover are currently being analyzed.

9) Study Title: Annual Forest Land Inventory of Utah

Permit No.: CANY-2011-SCI-0009

Principal Investigator: Renee O'Brien

Purpose of Scientific Study: The Interior West Forest Inventory and Analysis program is responsible for statewide inventories in eight states. The purpose of this ongoing inventory is to gather information on condition and trends of forest resources to assess plant diversity; fuels and potential fire hazards; condition of wildlife habitats; mortality and risk associated with fire, insects, or disease; and biomass, carbon storage, forest health and other general characteristics of forest ecosystems. Under the annualized inventory system, each field plot is visited once every 10 years, with approximately 10 percent of the total plots visited each year within a state. The FIA program produces a five-year report for each State.

Findings/Accomplishments for 2011: As part of the Annual Forest Land Inventory of Utah, field crews visited two plots within Canyonlands National Park during the 2011 field season. One location was found to be forest, and the field crew collected detailed vegetation information. The second location was determined to be inaccessible by foot travel. Site-specific summaries of field data from forest plots, in PDF form, will be sent to the designated NPS contact person. The results of this ongoing inventory are periodically updated and made available at www.fs.fed.us/rm/ogden/publications/.

10) Study Title:

Permit No.: CANY-2011-SCI-0010

Principal Investigator: Dana Witwicki

Purpose of Scientific Study:

Findings/Accomplishments for 2011:

11) Study Title: Investigation of the interaction of pre-existing joints and the fault system in the Cedar Mesa Sandstone in the Grabens Area, Canyonlands National Park

Permit No.: CANY-2011-SCI-0011

Principal Investigator: Heijn VanGent

Purpose of Scientific Study: The development of faults in the presence of pre-existing joints is not well understood, in this work we aim to study the effects of the well known, pre-existing joint system in the Canyonlands NP on the development of faults. We will further study the neotectonic deformation of the Needles District and we aim to study the timing and rates of deformation. These results will allow for better understanding of the development of the Graben area, fault dynamics, and the fundamental system of the early salt tectonics in sedimentary basins.

Findings/Accomplishments for 2011: A number of interesting observations resulted of this field work. The following paragraphs are quoted from the MSc thesis of Michael Kettermann (2011): "The Effect of Preexisting Joints on Normal Fault Evolution: Insights from Fieldwork and Analogue Modeling," submitted at RWTH Aachen University:

1. Some rare outcrops allowed the measurement of both heave and throw of graben-bounding faults. According to a simple trigonometric relationship bulk fault dips could be estimated by using these measured values. Derived dips are in the range of 63° to 75°. Respecting that erosion increases the apparent heave would shift the dips to slightly higher values, hence for following analyses fault dips between 65° and 80° were used.

2. By combining these dipping angles and estimated total throws along an EW oriented profile crossing eight grabens in the northern Grabens area, a total extension in the range of 6 - 16% was estimated.
3. Especially the less eroded graben walls in Devils Pocket and Devils Lane revealed the vertical joint geometry. We observed that the WNW-ESE striking joint set consists of two types of joints, one with larger spacing and depth cutting through the entire Cedar Mesa formation, and one with smaller spacing that often terminates after a few meters. Moreover, these joints are often inclined in different directions. However, the graben parallel joint sets seem to dip vertically and smooth vertical graben walls are interpreted as original joint surfaces.
4. The fact that one joint set remains parallel to graben bounding faults, even in the very south of the Grabens where fault strikes change from NNE to an almost E-W orientation, suggested a strong influence of joints on fault geometry, respecting that joints are believed to be older than the grabens.
5. The absence of movement indicators such as slickenlines or toolmarks and the instead observed smooth original joint surfaces, often thickly coated with calcite, indicated both a strong dilational component of the faulting and a localization of deformation at the preexisting joints.
6. Grabens crosscuts observed in Cross Canyon as well as a few outcrops in the northern section reveal that the graben floors often show internal faulting and even secondary horsts. In Cross Canyon the investigated graben floors dip towards the Colorado River due to higher dip-slip on one bounding fault.
7. GPR surveys came up with surprisingly good results for structures in up to slightly over 10 m depth, depending on the used antenna (400 or 100 MHz) and the sediment properties, especially the water content. As a kind of benchmark, a transition from loose eolianfluvial material to more compacted sediments was interpreted in about 8 to 10 m depth that was described previously by Grosfils et al. (2003) from seismic refraction data.
8. The most interesting profiles for the purpose of this work were the ones close to or across graben walls. Of these, the profiles at locations with apparently low deposition rates often show layers dipping towards the graben walls and/or a wedge-shaped thickening of layers towards the graben walls. This can be interpreted as evidence for ongoing horizontal offset, leading to a preferred deposition in the created voids. Profiles associated with higher sedimentation rates were found to contain sedimentary structures such as onset and foreset beds protruding towards the graben center. Further investigation and interpretation of these structures might reveal cycles of changing deposition and deformation rates.

12) Study Title: Effects of Climatic Variability and Land Use on American Drylands

Permit No.: CANY-2011-SCI-0012

Principal Investigator: Frank Urban

Purpose of Scientific Study: Previously assigned NPS study number: CANY-0048

Previously assigned NPS permit number: CANY-2010-SCI-0004

The American Drylands Project undertakes studies to understand past changes, measure ongoing change, and predict changes in physical and ecological landscapes and how these changes influence landscape stability, ecosystem dynamics, and human communities of American drylands. Arid and semi-arid lands compose about one half of the lower 48 states and are among the Nation's most sensitive regions to climatic variability and land-use practices. Combinations of natural factors (such as short-term climatic variability) and vastly expanding population, especially in the Southwest, are placing unprecedented pressures on our dry landscapes and their ecological resources. The existing and potential impacts make American drylands a national priority for understanding environmental change and its effects on both human dominated and natural systems. In particular,

interactions among land management, societal adjustment, and local to regional planning require contributions and collaborations across many arenas of natural and social sciences. Examples of key problems include physical impacts of drought and wet periods, ecosystem health (e.g., invasive plant species), human health, water quantity, carbon cycling, and impacts of wildfire. One of the biggest global change issues facing the Nation is the current trend of warming and overall drying of American drylands and models that show exacerbation of these trends during the next few decades (Seager, Science, 2008; NCAR, 2010 <http://www.cgd.ucar.edu> , link to drought). This project addresses the urgent need to understand and measure physical landscape change and its influence on ecosystems and the human communities that depend on ecological services such as water, productivity, and landscape stability. On the scale of ecosystems to physiographic regions of American drylands, we will develop new understanding of interactions among physical, biogeochemical, and human systems, and responses of these systems to forcing from climate and demographic change. With this understanding, we will forecast expectable, near-term changes in physical and ecological landscapes. We will provide information, forecasts, and educational materials to federal, state, local, and Native American agencies and communities, for their land-use planning, management of resources, and protection of human health. In the Canyonlands area these objectives are addressed largely through monitoring of environmental variables and dust deposition at the two CLIM-MET monitoring stations in the park and the two immediately adjacent to the park and at the ISKY regional dust camera near the ISKY ranger station, for monitoring project information see these websites.

<http://data.usgs.gov/climateMonitoring/region/show?region=americandrylands>

<http://esp.cr.usgs.gov/info/sw/clim-met/index.html>

Monitoring at these stations has been ongoing since 1998 with close relationships to other USGS research groups (Jayne Belnap, MOAB), University of Colorado (Jason Neff's Previously Assigned NPS study number, CANY-0013, permit number CANY-2010-SCI-0005) as well as longstanding collaboration with NPS researcher/manager Mark Miller.

Findings/Accomplishments for 2011: All sites were visited 2-3 times by USGS personnel in 2011. These site visits typically include onsite checks and calibration of environmental sensors, download of data, maintenance of instrumentation. Project overview and downloadable environmental data as well as publications listings is available at the following URL's.

<http://data.usgs.gov/climateMonitoring/region/show?region=americandrylands>

<http://esp.cr.usgs.gov/info/sw/index.html>

<http://esp.cr.usgs.gov/info/sw/clim-met/>

http://esp.cr.usgs.gov/info/regional_cams/index.html

Findings from data collected in 2011 will be presented at the Canyon Country Science Symposium in Moab, UT in March 2012.

Local and Regional Airborne Dust in the Canyonlands Region: Integrated Analysis of Digital Imagery, Total Suspended Particulate, and Meteorological Data Frank E. Urban, Richard L. Reynolds, Jason C. Neff, Daniel P. Fernandez, Marith C. Reheis, Harland L. Goldstein, Edmund E. Grote, Chris Landry. Additionally, two additional recent publications that employed data obtained under this permit are listed below. Reheis, M.C., and Urban, F.E., 2011, Regional and climatic controls on seasonal dust generation in the southwestern U.S.: Aeolian Research, doi:10.1016/j.aeolia.2011.03.008. Munson, S.M., J. Belnap, G.S. Okin. 2011. Responses of wind erosion to climate induced vegetation changes on the Colorado Plateau. Proceedings of the National Academy of Sciences 108: 3854-3859.

13) Study Title: Mexican Spotted Owl Occupancy: A Measure of Habitat Quality and Productivity in Utah

Permit No.: CANY-2011-SCI-0013

Principal Investigator: Brent Bibles

Purpose of Scientific Study: We propose to combine predictive habitat modeling with occupancy modeling to evaluate how habitat features influence Mexican Spotted Owl demographic parameters such as productivity and probability of site use. We will use protocol (hooting) surveys to determine owl occupancy within canyonland regions. We will measure geologic, topographic, and vegetative characteristics at each survey site and collect weather covariates using remote data loggers. Our study will be focused in Canyonlands and Capitol Reef National Parks and potentially expand to include most of southern Utah in the following year.

Findings/Accomplishments for 2011: A total of 67 hooting surveys were conducted between May 9th 2011 and August 15th 2011 in the Capitol Reef and Canyonlands areas. Within Canyonlands National Park, 34 surveys were conducted in the Needles District and 8 surveys in the Island District. A total of 8 surveys were conducted on surrounding Bureau of Land Management (BLM) lands and the remaining 17 surveys were conducted in Capitol Reef National Park. Surveys within the park were conducted at both historically occupied canyons and randomly selected canyons. A total of 11 Mexican spotted owls were detected (7 males and 4 females) at 7 different sites within the Needles District. In the Island District a total of 4 owls were detected (3 males and 1 female) at 3 different sites. All female owls were detected with a male and they were presumed to be a nesting pair. Single male detections were presumed to be solitary males without a nesting partner. Reproductive status was assessed during daytime visits to sites where a male and female owl were detected. Of the 7 sites within the Needles District, juveniles were detected at 2 different sites. Both sites produced 2 young each for a total of 4 juvenile detections. It was assumed that all juveniles successfully fledged from the nesting sites, as no remains were recovered and all juveniles were observed doing well at 3-4 months of age. Two additional sites where pairs of owls were detected earlier in the season were presumed abandoned. These sites were re-visited approximately 3 weeks later and there was no longer any evidence of owl presence within the apparent nesting caves. On BLM land near the Island District another pair of owls successfully produced a total of 3 juveniles. This is considered a rare occurrence as the average number of young produced is typically 2. Geologic, topographic, and vegetative characteristics were not collected during this field season and will be collected during May-August of 2012. Travel conditions in the park were extremely challenging during the monsoon season leading to the closure of several park roads and trails.

14) Study Title: Assessment of Stocked Razorback Sucker and Colorado Pikeminnow Reproduction in the Lower Green River via Larvae and Young of Year Collections.

Permit No.: CANY-2011-SCI-0014

Principal Investigator: Paul Badame

Purpose of Scientific Study: This project targeted determining and monitoring early life stages of endangered fish in the Colorado River drainage, specifically the Colorado pikeminnow (*Ptychocheilus lucius*) and the razorback sucker (*Xyrauchen texanus*). Monitoring of young-of-the-year (YOY) Colorado pikeminnow was initiated in 1986 within the upper Colorado River basin as part of the Interagency Standardized Monitoring Protocol (ISMP). The ISMP sampling in the lower Green and Colorado Rivers was proposed to monitor recruitment success of first year endangered fishes, to correlate cohort strength and condition to abiotic and biotic parameters, and to provide data for a predictive model measuring future cohort strength. Since its inception, the ISMP protocol has been updated to refine its scope and methods to focus not only on pikeminnow but all small-bodied fishes allowing for assessment of other projects such as nonnative control actions. A comprehensive synthesis of the effect of changes in physical habitat (as a function of flow and flow variability) and other environmental conditions on the small-bodied fish community (emphasis on Colorado pikeminnow) is underway. Another aspect of this project is designed as a pilot study to determine the presence/absence of early life stages of endangered

razorback sucker in lower Green River. By the mid 1990s most wild riverine adult razorbacks in the Green River basin were limited to one population in the middle Green River with an estimated size of about 500 adults (Modde et al. 1996). Although sampling from 1992-96 did verify the presence of larval razorback in both the middle and lower Green River it was believed that mortality rates on those larvae were very high and did not provide any significant recruitment into the wild population (Muth et al. 1998). Habitats were identified for razorback sucker larvae as ephemeral shoreline, ponded lower portions of flooded tributary streams, side canyons, washes, canals, and channels (Muth et al. 2000). Historic collections sites for larvae were Millard Canyon, the confluence of the San Rafael River, and Green River Valley area. By 2000, wild adult razorback suckers in the Green River Basin were very rare and the few remaining have likely perished (Bestgen et al. 2002). Stocking of hatchery reared razorback sucker in the Green River basin began in 1999 as a means to augment the population and continues through this current time (US Fish and Wildlife Service 2002). Thus, all current reproduction observed is likely by stocked adults. Determining the reproductive success of stocked fish in the Green River is key to understanding their ability to maintain a viable self sustaining population. During sampling for adult Colorado pikeminnow (2001-2003 and 2006-2008; UDWR unpublished data), within the lower Green River, the occurrence of adult razorback captures had increased greatly from 9-10 individuals per year to an average of 320 captures between 2006 and 2008. In addition, during the 2007-08 adult pikeminnow sampling an increased number of ripe adult razorbacks have been captured throughout the lower Green River and in two specific locations congregations of ripe razorbacks displaying spawning behavior have been observed and captured. In 2008, three age 1+ razorbacks were captured within the lower Green as well. This progression of events over the last three years strongly suggests that adult stocked razorback are now persisting in large enough numbers within the lower Green to facilitate successful spawning. Successful spawning among stocked razorback is an important component of a viable recovery for the species. Determining the timing, locations, and relative extent of larval recruitment will help define the success of the species. Sampling focused on year one survival of larvae will provide information about potential road blocks to recruitment of young suckers into the adult population.

Findings/Accomplishments for 2011: Larval/juvenile Razorback monitoring: Light trap samples were collected at sites between river miles 119.5 and 33.7 during the period of 3 May to 27 July 2011. In total 178 light trap samples were collected and of those, 68 samples were sent to the CSU larval fish lab for identification. Sampling began when main channel temperatures reached 14°C. A 1 meter kick seine was used to collect 25 larval fish samples from flooded tributaries, side channels, backwaters, and embayments between 23 July and 25 July 2011. A total of 9 of samples were sent to CSU larval fish lab to be identified. Timing of other projects and an extended high spring run-off made it impossible to seine for juveniles in August.

YOY pikeminnow sampling: Lower Green River: Reach 3 Annual monitoring for YOY Colorado pikeminnow began on September 11 and completed on September 13, 2011. Seining was conducted on the Green River from river-mile 120 (Green River State Park) to river-mile 0 (confluence with the Colorado River). A total of 27 of 48 possible backwaters were sampled in 17 of 24 sub-reaches in the lower Green River. The total area seined in Reach 3 in 2011 (1796 m²) was lower than the 26-year average (3578 m²). In the lower Green River, 17 YOY Colorado pikeminnow were captured and measured. All fish were sorted, identified and enumerated in the field. Thirteen of the 17 fish were released alive; four died during the enumeration process. This is the lowest number of YOY Colorado pikeminnow captured in the 26 years of the study (17 were also caught in 2001). This is considerably lower than the 10-year average (193.70 fish/year), 15-year average (222.27 fish/year), and 26-year average (482.46 fish/year). The CPUE this year was 0.95 fish/100m². The average length of YOY Colorado pikeminnow was 22 mm. The Nonnative captures were only enumerated during the first seine haul in each primary habitat in the lower Green River. Total catches

in Reach 3 included six nonnative species and were once again dominated by nonnative cyprinids. These included red shiners ($n = 1,842$), sand shiners ($n = 1,096$), fathead minnows ($n = 314$), common carp ($n = 15$), black crappie ($n = 8$), and channel catfish ($n = 6$).

Task 3: Lower Colorado River: Reach 1

Annual monitoring for YOY Colorado pikeminnow in Reach 1 began on September 12, 2011 and was completed on September 14, 2011. Seining on the Colorado River was conducted from river-mile 110 (Cisco Landing) to river-mile 0 (Confluence with the Green River). A total of 23 of 44 possible backwaters were sampled in 16 of 22 sub-reaches in the Colorado River. The total area seined in Reach 1 in 2011 (1195.2 m²) was lower than the 26-year average (3046 m²). Reach 1 water temperatures ranged from 19 to 23 °C in the main channel and 18 to 30 °C in backwaters. Colorado River flows (measured at USGS Gage #9180500 near Cisco) fluctuated between 5,300 cfs and 5,050 cfs over the three days of sampling. These flows are above the mean daily values (3,820 - 3,950 cfs) for this time of year based on the period of record for this gauge (1914 - 2011). In the lower Colorado River, 59 YOY Colorado pikeminnow were captured and measured. All fish were sorted, identified and enumerated in the field. All fish captured were released alive. The number of Colorado pikeminnow captured is higher than the 10-year average (41.7 fish/year) but lower than the 15-year average (63 fish/year), and the 26-year average (130.62 fish/year). The CPUE this year was 4.94 fish/100m². This is higher than the 10-year average CPUE (1.94 fish/100m²), the 15-year average CPUE (1.91 fish/100m²), and the 26-year average CPUE (4.32 fish/100m²). The average length of YOY Colorado pikeminnow in 2011 was 24.15 mm, which is lower than the 10-year average (39.04 mm). Other native species captured in the Colorado River included 31 flannelmouth suckers, 3 *Gila* spp., and 2 speckled dace.

15) Study Title: Assessing Climate Refugia and Connectivity for Desert Bighorn Sheep

Permit No.: CANY-2011-SCI-0015

Principal Investigator: Clinton Epps

Purpose of Scientific Study: (Note: the Detailed Implementation Plan for this study has been signed by Kate Cannon, the Superintendent of the Southeast Utah group, and Jeff Troutman, formerly the Resource Management Division Chief for the Southeast Utah group.)

Management of wide-ranging species with fragmented distributions offers a difficult challenge on NPS lands, particularly in the face of regional or global shifts in climate. Desert bighorn sheep (*Ovis canadensis nelsoni*) exemplify that challenge. This charismatic, desert-adapted animal exists in relatively small, sometimes isolated populations scattered across the arid southwestern United States. Recent research has firmly linked desert bighorn sheep persistence and genetic diversity with climate variation (Epps 2004; Epps et al. 2004, 2006), and reproduction and survival for this species are predicted in large part by precipitation and temperature (Wehausen 2005). However, high rates of population extinction (e.g., Wehausen 1999) may be mitigated by recolonization from other nearby herds (e.g., Epps et al. 2010). While climate is intractable to management at the regional level, maintaining connectivity among existing populations of bighorn sheep will provide the best means for offsetting the unpredictable but potentially devastating changes in precipitation and temperature predicted for the American southwest. Historically, management of desert bighorn sheep was approached on a population by population basis. Growing recognition that desert bighorn sheep are subject to metapopulation dynamics (frequent extinction and recolonization of small populations in discrete habitat patches) has made it clear that desert bighorn sheep must be managed at a regional level. This is particularly true given that many processes that affect bighorn sheep, such as climate variation or climate change, are correlated at regional scales. Human-driven landscape change is also happening at an unprecedented scale, as demonstrated by proposed massive

solar developments in the Mojave Desert and the US-Mexico border fence (Flesch et al. 2010). National Park Service lands support significant populations of desert bighorn sheep in at least nine parks in four states. However, in many cases the connectivity of those populations and with other populations in each region is unclear. Also unclear are the roles of those herds in regional context: are they core populations, peripheral populations, or do they serve as a critical link for gene flow and dispersal between other populations in the region? Lastly, although region-level predictions from global climate change models are often highly variable, how will anticipated changes in temperature and precipitation affect desert bighorn metapopulation structure and habitat? Despite these uncertainties, ongoing research on desert bighorn sheep has created unprecedented opportunities to evaluate the role of bighorn sheep populations on NPS lands in the context of metapopulation persistence and climate change. We propose to use a combination of new and existing datasets to 1) analyze genetic diversity and metapopulation structure of desert bighorn on NPS and pertinent surrounding lands; 2) optimize connectivity models by augmenting existing genetic datasets; 3) explore metapopulation persistence under different climate change scenarios; and 4) identify regional refugia for desert bighorn sheep in the context of NPS lands and climate change.

Findings/Accomplishments for 2011: We collected over 500 bighorn sheep fecal samples from national park lands and adjacent public lands in 2011 for genetic analysis. Efforts specific to Canyonlands NP are as follows:

We collected 36 samples between July 19 and November 22 in the Shafer Canyon, Salt Creek, Mesa Arch, and North Needles areas, and along the Colorado River near the eastern park boundary. Fecal samples will be genotyped and genetic data will be analyzed, in combination with previously collected/genotyped samples, to reveal genetic structure of desert bighorn sheep populations in and near national park lands. A spatial database and full report including locations of fecal samples, group sizes and locations of bighorn sheep observations, genetic data, and important waterholes will be provided to NPS at the completion of the study.

16) Study Title: NCPN Springs Monitoring in Canyonlands National Park

Permit No.: CANY-2011-SCI-0016

Principal Investigator: I&M (NCPN)

Purpose of Scientific Study: The National Park Service's Inventory and Monitoring Program (NPS I&M), in collaboration with 32 monitoring networks, are charged with monitoring natural resources. Vital signs represent a select set of physical, chemical and biological elements and processes of park ecosystems that are chosen to represent the overall health and condition of a park's resources. Together, the Northern and Southern Colorado Plateau Networks (NCPN and SCPN) have developed conceptual models of key ecosystems and identified an integrated set of vital signs for tracking resource conditions at 35 NPS units within or near the Colorado Plateau (Thomas et al. 2004, O'Dell et al. 2005). Spring and seep systems are a high priority vital sign for the NCPN (O'Dell et al. 2005). Spring and seep systems are disproportionately high in biodiversity relative to their spatial extent due to the year-round or at least frequent availability of water. Many springs are closely tied to regional climate and local weather patterns. Monitoring the status and trends of spring and seep ecosystems can provide park managers with information on the variability of spring and seep systems, early warnings of system degradation, and the impacts of climate change.

Specific objectives of the springs and seeps monitoring effort are to determine the status and trends in:

- 1) water quantity
- 2) rare plant density
- 3) vegetation species composition and cover

Monitoring will also produce status information on water quality, exotic plant and animal species presence, and anthropogenic disturbance.

Findings/Accomplishments for 2011: NCPN Ecologist submitted manuscript to Western North American Naturalist on springs across an anthropogenic gradient. Completed the basis for an NRTR Report for project that examined anthropogenic impacts to springs in 6 NCPN parks and surrounding lands, however we have not yet submitted the report to the NRTR series because we are waiting for peer review comments to come back on the journal manuscript, as we want to make sure the two conclusions match. Gathered more baseline information at CANY. Held discussions with SEUG to determine long-term monitoring sites and allocation of resources. Developed long-term sampling designs. Completed power analysis and evaluated long-term trends in sites sampled by SEUG.

17) Study Title:

Permit No.: CANY-2011-SCI-0017

Principal Investigator: Todd Parr

Purpose of Scientific Study:

Findings/Accomplishments for 2011:

18) Study Title: Colorado River Tamarisk Biological Control Monitoring Project: Loma, Colorado to Hite, Utah and Green River, Utah to Hite, Utah

Permit No.: CANY-2011-SCI-0018

Principal Investigator: Lindsay Clark Tate

Purpose of Scientific Study: The purpose of this study is to support a body of knowledge to determine the value of the tamarisk leaf beetle, *Diorhabda elongata*, as a tamarisk biocontrol agent, on the Colorado and Green Rivers from Loma, CO and Green River, UT to Hite, UT. The four goals of this study are to obtain data concerning the dispersal and establishment of *D. elongata*, measure the efficacy of the beetle in controlling tamarisk, monitor the safety of biological control, and to ascertain the impact of biocontrol on riparian ecology. The overall impact of *D. elongata* on western ecology is not well understood. Preliminary studies show that local birds and generalist arthropods gain a significant food source with the introduction of the beetle (Dudley and DeLoach 2004, DeLoach et al. 2004, Herrera et al. 2001). This is beneficial for tamarisk ecosystems as they support less arthropod abundance than native vegetation (Stevens 1985, Shafroth et al. 2004). Defoliation by *D. elongata* also immediately reduces the amount of water tamarisk is able to transpire (Pattison et al. 2006), increases branch mortality, decreases flower and seed production, and in some situations causes plant mortality (Kazmer et al. 2006). Among factors most critical to tamarisk biocontrol success is the ability to predict and control beetle dispersal and establishment. Tamarisk mortality in cage tests was achieved following three sequential seasons of defoliation. Initial field studies indicate that more seasons of defoliation may be required to achieve tamarisk die off. In some instances beetles avoided plants that had been defoliated the year before, affording the tamarisk a recovery period and decreasing chances for mortality (Dudley and DeLoach 2004). Thus, ensuring beetle population longevity in any one area is essential to successful tamarisk control. Data collection will provide information to support the three major long-term research objectives shown below with their correlating short-term objectives:

(1) To obtain data that will aid in the future prediction and control of *D. elongata* dispersal and establishment. Gathering such data is invaluable to predict patterns and rates of eventual tamarisk mortality rates. Thus, the first immediate objective is to: (a) track largescale dispersal patterns of *D. elongata*.

(2) To measure the efficacy of *D. elongata*, in the control of tamarisk. Efficacy data will provide critical information to biocontrol viability. Therefore, the second immediate objective is to: (b) measure tree stress by recording changes in tree morphology (i.e. defoliation). (3) To ascertain the safety of *D. elongata* as a biological control agent. The possibility of biocontrol agents switching hosts is a concern. Although there are no recorded host-plant switches in weed biocontrol it is prudent to note any feeding, damage, beetle development, or population suppression of non target plant populations. For this reason one objective will be to: (c) routinely survey non target plants for the presence of *D. elongata*. Beetles have been found on other plants but in no instance have they persisted or impacted plants other than tamarisk. (4) To study the impact of *D. elongata* on riparian ecology. To date data shows an increase in other non-native plants (kochia, Russian knapweed and perennial pepperweed) in tamarisk defoliation areas. This information was gathered at sites (Lovelock, NV and Pueblo, CO) with little opportunity for other vegetation to establish. Thus, another objective is to: (d) collect a larger database of vegetative response to tamarisk defoliation. These objectives represent research needs identified by several consortia of scientists and practitioners such as the Saltcedar Biological Control Consortium of Texas, New Mexico, and Mexico and participants in the Tamarisk Research Conference held in Ft. Collins, CO in October of 2006. The results of these western Colorado research objectives will inform ongoing research analyzing *D. elongata*.

Findings/Accomplishments for 2011: Surveys occurred: 8/11/11-8/15/11 Colorado River, 8/11/11-8/15/11 Green River In Mid-August, moderate to high beetle populations were found throughout the Colorado River segment from Potash boat ramp to the confluence with the Green River. High densities (26 or more beetles/sample) were found at 18 of the 49 points (37%) taken throughout this section, comparatively moderate densities (5-25 beetles/sample) were found at 23 points (47%). Only 5 points (10%) were recorded showing low densities (1-4 beetles/sample) and 3 points didn't have any beetles present. Defoliation within the Colorado River segment from Potash boat ramp to the confluence with the Green River was also found at mostly moderate to high levels. Of the 49 points collected, 39 (80%) showed tamarisk defoliation levels of 21% or higher. No defoliation was found at 6 points while 4 points showed 5% to 20% defoliation on tamarisk; these points were found in between other points that exhibited moderate to high defoliation levels. Beetle presence was found at every monitoring point on the Green River from Mineral Bottom boat ramp to the confluence with the Colorado River. Of the 49 points, 22 (45%) were recorded with high densities (26 or more beetles/sample); the highest population density found was at river mile 14 with 462 beetles. Moderate beetle densities (5-25 beetles/sample) were found at 25 points (51%), while only 2 points had low densities (1-4 beetles/sample). All of these density variations were interspersed throughout this river segment. Even though the beetle populations expand throughout the entire river section, defoliation levels on the Green River are comparatively lower than the section on the Colorado River. No defoliation was recorded at 7 points (14%), while 15 points (30%) had low defoliation levels 5% to 20% and 27 of the 49 points collected (55%) showed tamarisk with defoliation levels of 21% or higher. During the surveys tamarisk leaf beetles were recorded feeding only upon tamarisk.

19) Study Title: Repeat Photography of Cataract Canyon and Vicinity, Southern Utah

Permit No.: CANY-2011-SCI-0019

Principal Investigator: Robert Webb

Purpose of Scientific Study: From 1991 through about 1995, our research group matched approximately 270 photographs of the Colorado River in Canyonlands National Park, particularly in Cataract Canyon. Of these, 60 were originally taken during the Brown-Stanton expedition of 1889 and 25 by the 2nd Powell Expedition in 1871. We propose to

rematch these photographs and to assess mortality and recruitment information for common species of desert and riparian vegetation along the river corridors.

Findings/Accomplishments for 2011: We have replicated approximately 45 of the 60 Stanton images of the river corridors through Canyonlands NP. One more river trip planned for the summer of 2012 should complete this work.

20) Study Title: Characterization of Permian White Rim Sandstone in southeastern Utah: Iron oxide concretions, and relationships to fluid flow

Permit No.: CANY-2011-SCI-0020

Principal Investigator: Marjorie Chan

Purpose of Scientific Study: The Permian White Rim Sandstone is a striking white unit of that forms a resistant rim in the Canyonlands area, prominently visible to many visitors to Canyonlands National Park (CNP), Dead Horse Point State Park, and Glen Canyon National Recreation Area (GCNRA). Geologically, the White Rim is a porous, eolian formation with significant bleaching and iron oxide concretions that collectively record the history of iron cycling and fluid flow. Although this unit is distinctively white colored, it is stratigraphically bounded by red, fine-grained formations both above and below it. The general objective of this geologic study is to understand why the White Rim Sandstone is white (bleached), and document iron oxide concretions (e.g., cemented mineral masses) and physical properties (e.g., porosity and permeability) that are important indicators of the fluid history through the rock. Models that explain the genetic linkage of sandstone coloration and iron oxide concretions have only been developed in the last decade, and have not yet been applied to the White Rim Sandstone. The focus of the research is Permian exposures of CNP and GCNRA in parts of Wayne and Garfield counties of southeastern Utah. This is the physical area where there is the remaining record of the potential fluid responsible for the bleaching (e.g., hydrocarbons) and where the recently recognized iron oxide concretions occur. The results of the proposed research will increase our knowledge about fluid flow history in this region of the Colorado Plateau, with baseline applications to permeability heterogeneities in eolian facies. Overall the results will enhance public understanding on the geologic significance of the White Rim Sandstone (e.g., why it is so white and distinctive and how it got that way), and how iron has been nature's artistic pigment over geologic time. This is only a scientific geology study; it is not intended to evaluate the tar sand resource or any aspects of extraction. The intended use of the results is to increase scientific knowledge and understanding of the natural landscape, which will contribute evaluation of the park resources in geologically important sites. Key words: White Rim Sandstone, geology, eolian, bleaching, concretions. (Note: 1 page of all figures 1-5 is in separate file upload)

Findings/Accomplishments for 2011: This porous, eolian formation contains significant bleaching and iron oxide concretions that collectively record the past history of iron cycling and fluid flow in the subsurface. Iron oxide concretions (cemented mineral masses) comprise the physical evidence of diagenetic (secondary) fluid flow through the primary porous host rock. Although this unit is distinctively white colored, it is stratigraphically bounded by red, fine-grained formations both above and below it. The general objective of this geologic study is to understand why the White Rim Sandstone is white (bleached), and document iron oxide concretions (cemented masses) and physical properties (e.g., porosity and permeability) that are important indicators of past fluid flow regimes. The iron cycling and heterogeneity of this White Rim system has not been previously explored, but will have broad applications to other eolian sandstone deposits.

We have made several trips to the field localities and established the important facies. The well-exposed White Rim Sandstone lithofacies in the study area include horizontal-bedded sandstones (sand sheet), cross bedded sandstones (eolian dune), and mottled to

rippled sandstones (marine reworked veneer). We also measured stratigraphic sections, sampled concretions and host rock, and made in situ (in place) outcrop permeability measurements with a handheld permeameter. Measurements were taken parallel and perpendicular to stratification. We can evaluate anisotropy and heterogeneity through quantification of outcrop permeability data and characterization of the iron oxide concretions versus the host rock. These permeameter measurements will be compared with traditional core plug porosity and permeability data that should be completed in the next several months. Preliminary data indicate that within the crossbedded sandstone host, grainflow laminae have higher permeability than wind ripple laminae. The sandsheet deposits have the highest permeability due to the coarse-grain sand composition. The greatest variability of permeability exists in the mottled to rippled sandstones deposited as the marine veneer. There is a marked permeability reduction in the fine-grained overlying Triassic deposits that would have been the hydrocarbon seal. The characterization of the iron oxide concretions includes study of the physical distributions, geometries, and spacings as well as microscopic textures and mineralogy. From the 11 samples collected thus far, we have done field spectrometer measurements for mineralogy, and have just received back petrographic thin sections for our microscopic analyses. We have also made some comparisons to other existing collections that contain relevant White Rim data. We hope to be able to get an approximate date of the timing from (U-Th)/He dating. Our project is still in progress and we expect to continue field studies, mapping, stratigraphic sections, sampling, and laboratory analyses.

21) Study Title: Normal fault geometry and evolution in the Needles District, Canyonlands National Park

Permit No.: CANY-2011-SCI-0021

Principal Investigator: Simon Kattenhorn

Purpose of Scientific Study: To study normal fault systems that define the Grabens region in the Needles District of Canyonlands National Park. We will map out fault geometries with specific focus on the linkages between overlapping fault segments. The work will allow us to develop conceptual models for fault evolution that will be applicable to normal fault systems throughout the solar system.

Findings/Accomplishments for 2011: Fieldwork was undertaken in October 2011 in the designated field area in the Grabens/Needles district. Graduate student Matt Blakeslee examined normal fault systems in an attempt to identify relay ramps between fault segments. These relay ramps were characterized based on their surface geometries (sense of tilt) relative to the nature of the fault segments that bounded them (fault length, throw, geometry). His goal was to collect spatial information (x-y-z coordinates) of fault traces (footwall and hanging wall cutoffs) to generate fault throw profiles and to map out structural geometries specifically; however, due to equipment malfunction with our real-time differential GPS mapping system, he was unable to collect this data. A second field season may thus ultimately be necessary. We have purchased new GPS equipment for that task and will consider revisiting the region in the Fall of 2012 or Spring of 2013. The descriptive aspects of the fault systems will be included in Matt Blakeslee's MS thesis (May 2012 completion) as part of a larger group of analogous fault examples from multiple locations. Ultimately, the work will be considered for publication in scientific journals.